Databus in a Box - Scalable Electronic Integration Solutions for Tactical Trucks

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ABSTRACT

Modern Army Trucks have undergone an evolution that has spanned sixty-plus years and countless iterations of drive-train and system technology. From the erstwhile mechanically controlled internal combustion engines of days gone by to the robust electronically managed networks of today's warhorse tactical wheeled vehicles, the ever-present requirement to integrate and maintain these technologies remains. For some systems in the Army's inventory, this is a more pressing problem. A great many vehicles in Army service lack the network-based electronics to integrate new age electronic control modules (ECU's). This missing ingredient is paramount in enabling the use of embedded diagnostics computing to troubleshoot the entire system via networked communications, and to host diagnostics software such as interactive electronic technical manuals (IETMs).

The costs associated with integrating these electronic networks into Army trucks are high, sometimes running into the tens of thousands of dollars per vehicle. For lower cost platforms such as High Mobility Multi-purpose Wheeled Vehicle (HMMWV) (figure 1), this cost is prohibitive. As technologies in the areas of engine and transmission evolve to be available as only electronically controlled subsystems, the need to create an affordable, scalable module to serve as a low cost electronic integration point becomes necessary. The approach calls for this module or "data bus in a box" to have standard vehicle and electronic information interfaces, suitable processing to handle many data inputs, designed-in scalability for non-electronically controlled sensor inputs, and the requisite ruggedization properties to handle the rigors of today's military environment.

Figure 1: HMMWV

INTRODUCTION

The US Army ground vehicle fleet currently exceeds 250,000 and is increasing with new platform acquisitions to support the Future Force. The Army faces many logistical challenges in supporting the current fleet, from maintenance actions to asset tracking. The burden of logistics will only increase as more vehicles are fielded and join the fleet. Army logisticians need an information system to assist in determining vehicle maintenance actions, performing asset tracking, and determining vehicle health and readiness levels. With ground

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vehicles deployed in various areas of the world, these challenges multiply.

Currently, the only method a logistician retrieves any vehicle diagnostic data is through a vehicle maintainer (i.e. a soldier). Soldiers use Portable Maintenance Aid (PMA) devices such as the Maintenance Support Device (MSD) (figure 2) or the Soldier's Portable On-system Repair Tool (SPORT). These devices require soldier participation to analyze the vehicle which identifies system faults and maintenance failures when they occur. These devices do not enable any type of predictive failure analysis of components nor do they offer any real-time fault detection. One major challenge is to eliminate the need for a soldier in the diagnostics process by embedding the diagnostic data retrieval capabilities directly into the ground vehicle platform which will enable real-time communications between vehicle and maintenance specialists.

The US Army National Automotive Center has been performing research and development in the area of wireless embedded diagnostics and prognostics over the past five years. The main objective for this program is to develop a cost-effective solution to equip the current fleet with integrated diagnostic data capture capabilities and

Figure 2: Maintenance Support Device

aid logisticians in supporting the fleet from afar without requiring a soldier to interface with the vehicle directly. To provide these capabilities at an affordable price, the Army must leverage existing communication and logistic networks; seamless interoperability with these networks is imperative to the success of this system. The proposed system must also be flexible enough to interface with a vast array of diverse network systems and protocols, for requirements change as interfaces to these networks and systems change.

TACTICAL TRUCK APPLICATIONS

The databus in a box (DBIB) solution seeks to provide the level of scalability needed in providing generic sensor integration, interfaces to existing communication and logistic networks, messaging capabilities, asset/inventory tracking (AIT), and the ability to store and transmit diagnostic data from any Army vehicle platform. The applications to this solution could be integrated into tactical truck platforms to include vehicles with and without vehicle databuses. Vehicles with existing databuses could gain capabilities of integrating non-databus compliant sensors such as tire pressure gauges, load handling sensors, and asset tracking technology. By inserting a DBIB solution into vehicles without databuses, like the HMMWV, it can enable fundamental diagnostic analysis to a platform that never had the capability from the start; which will enhance the overall maintainability of the vehicle.

NEEDS AND REQUIREMENTS LEAD TO GROWTH

The scope of developing a DBIB solution has lead to an expansion in capabilities. One particular issue that has surfaced is the integration of generic sensors on current vehicle platforms. The DBIB is designed with an open architecture, which helps easily integrate these types of sensors and helps bind them to a central data collection point. A second focus that has affected development is secure wireless communication. The Army currently requires that all wireless transmitting devices have a level of security that complies with NIST's FIPS 140-2 level 2 security standards. The DBIB shall meet the level of security needed to transmit over Army secure networks and shall hold the capability of upgrading to new security algorithms when they are enforced and available.

DIAGNOSTICS FOR AN AGING FLEET

To further develop the concept of equipping non-data bussed vehicles with diagnostic solutions; let's talk about the HMMWV platform. It has strength in numbers, being the most frequently utilized vehicle in the Army's truck fleet, at over 100,000 vehicles. By virtue of the numbers in service alone, the vehicles' diagnostic health is of paramount importance, but also, it stands to reason that the HMMWV is relied upon to support most if not all logistics based functions that the Army requires to be successful in the battlefield. This includes the transport, in convoys, of critical operations and sustainment supplies, ammunition, and combat service support materials such as repair parts and maintenance support teams. Since the HMMWV platform is currently not equipped with any prevalent electronics to support the on-board "inventory" of stored supplies, or relay relevant logistics data to other vehicles or to fleet managers, the insertion of a "smart black box" is a natural fit for insertion. Additional functions over and above diagnostics connectivity and logistics management include intra-vehicle, secure voice over internet protocol (sVoIP) or "convoy intercom". This function conceptually provides for redundancy in voice communications in areas where line of sight radio cannot be used, such as mountain ranges and urban warfare environments.

FORM, FIT, AND FUNCTION ADDITIONS TO EXISTING DIAGNOSTIC CAPABILITIES

Those vehicle platforms that are designed with embedded diagnostics data architecture such as Family of Medium Tactical Vehicles (FMTV) (figure 3) and Heavy Expanded Mobility Tactical Truck (HEMTT) (figure 4) could also potentially benefit from the addition of a scalable smart "black-box". These vehicles as well as other variants in the tactical truck fleet are potentially ready for integration with sensor varieties not readily equipped to talk to data bus architecture. The databus technologies used in these platforms allows for many connection points to data inputs on the architecture, without any impact on data throughput or latency. Provided the black box is small enough to be integrated in a safe assessable location with the vehicle system, can be integrated to serve as a data "funnel point" to collect data. Many of these sensors are analog in nature and deal with capability areas not networked to the architecture or supported by an electronic control unit (ECU). Examples of this include: embedded oil quality sensing, smart battery monitoring, and electronic strain gauges designed to monitor the forces that cause weld joints to break and suspension elements to fail due to over-loading of cargo areas and up-armoring of the vehicle system. Benefits of introducing this black box technology would be the following: enabling the integration of the potential suite of add-on sensors in a manner that allows them to communicate with the established databus network and using software to make the mix of data impulses all look the same to the architecture. This is not a trivial task, given the different varieties of analog data that could manifest on this miniature network within a network.

Figure 3: Family of Medium Tactical Vehicles (FMTV)

Figure 4: Heavy Expanded Mobility Tactical Truck (HEMTT)

ASSET TRACKING

The Army faces challenges in not only tracking where vehicles are located around the world, but also the inventory of each supply vehicle. Imagine awaiting delivery of a much needed replacement part needed to repair a ground vehicle in theater using the current supply system. One may be able to find out what the last processing station was for the part, but the resolution of its location is constricted due to the lack of a real-time data architecture.

One solution to this madness may be an implementation of a Radio Frequency Identification (RFID) system that taps into the network via the proposed DBIB solution. This system would be comprised of RFID tags affixed to each part or package, a RFID reader mounted aboard the transporting vehicle, and data acquisition software that handles storage and retrieval of RFID data in a database driven, backend system.

SINGLE ARMY LOGISTICS ENTERPRISE

The Army has invested a large amount of funding towards an over-arching Single Army Logistics Enterprise (SALE) architecture to enable capabilities such as Total Lifecycle Systems Management, Conditions Based Maintenance, and End-to-End Customer Service. The strategy for making the SALE architecture a reality is to tailor a commercial Enterprise Resource Planning (ERP) software product to fit the Army's needs and requirements. The architecture takes a system of systems (SoS) approach by integrating disparate database systems and rolling it up into one centralized user interface. The main pillars of the SALE architecture is comprised of three ERP solutions: Logistics Modernization Program (LMP), Global Combat Support System-Army (GCSS-A), and Product Lifecycle Management Plus (PLM+). Each of these ERP solutions use SAP as the software.

One key element missing from this architecture is the vehicle interfaces and data capture systems aboard ground vehicles. This element must be developed to interoperate with these future logistics systems. One objective of the DBIB design is to enable logisticians to reach the vehicle and extract valuable data in real time. The optimum way to achieve this is to use and leverage this SALE architecture and any existing or future communication networks.

Common Logistics Operating Environment

Another element that fits in the SALE space and acts as an enabler to integrate the distributed operational networks and disparate data stores is Common Logistic Operating Environment (CLOE). The vision of CLOE is of a Common Logistics Operating Environment that is enabled through the development of an Army Integrated Logistics Architecture (AILA) that fuses information, logistic processes, and PM developed platform/soldier embedded sensor-based technologies to support tactical, operational and strategic logistics echelons of war in a joint integrated logistics environment.

The success of CLOE is predicated on that logistics environment being defined by data standards and an overarching logistics integrated architecture to ensure interoperability & net-centricity. Also critical to success is the development the logistics operational architecture that underpins army logistics transformation. That architecture starts with data elements that are manifested on platform and can be retrieved and distributed to the Army enterprise. DBIB as an appliqué can be an important add on to enable this data transaction, particularly for the non databussed platforms, but also as a means to integrate additional sensors that may not be bus compliant.

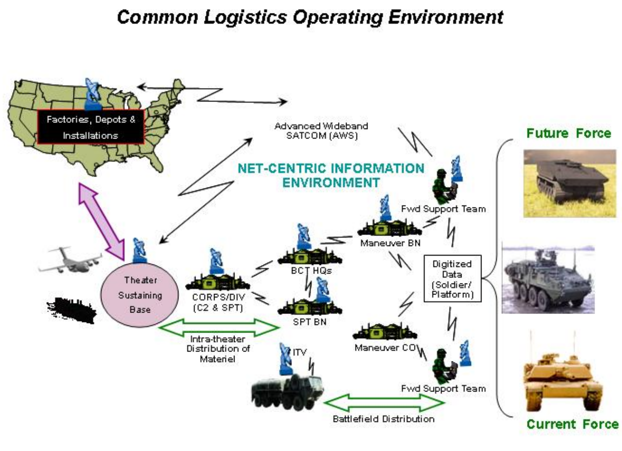

Figure 5: Common Logistics Operating Environment

SECURE WIFI COMMUNICATIONS

The Army currently uses Wi-Fi as the main communications medium to transmit wireless data, due primarily to the availability of commercial-off-the-shelf technology. Wi-Fi, when used in conjunction with a FIPS 140-2 level 2 encryption client, provides a high bandwidth (up to 11 Mbps) short range (up to 300 feet for optimal operation) protocol capable of replacing wired Local Area Networks (LAN) and is advantageous to apply in mobile networks such as those applied in ground vehicles. Wi-Fi, or more specifically 802.11b, is the protocol of choice for The Combat Service Support Automated Information System Interface (CAISI), the US Army's wireless network standard. All of the communications (incoming and outgoing) from the proposed solution will be encrypted with the approved encryption algorithms and will have the ability to seamlessly communicate over any CAISI mesh network.

PROJECT RISKS

There are many risks involved in developing a fully functional data acquisition system. One major risk involved is the bulkiness of the box and the risk that it will not fit within the space constraints of current and future vehicles and still have enough computing power to perform complex encryption/decryption algorithms.

Another key risk in designing a DBIB solution is the unit costs versus the functionality the solution will provide. Limited re-engineering and recapitalization budgets require these types of technology insertions to be as cost efficient as possible target unit costs should reflect values in the hundreds of dollars range. This would help a Program Manager to decide more favorably towards choosing the technology and get the capability to the field. The advantage of doing it during a recapitalization program mitigates any field installation costs and any inconveniences it may cause the fleet managers.

CONCLUSION

The need for development of a DBIB system comes from the need to integrate affordable scalable diagnostics data collection devices across the Army's tactical truck fleet. With only about a quarter of the Army's truck inventory being outfitted with serial data networks, and recapitalization budgets being very limited, it becomes even more important to take advantage of advances in technology to create inexpensive options to achieve this goal. The solution must be adaptable to applications and platforms equipped with ECU networks for the purpose of adding sensing technology that is not databus compliant.

Areas of consideration, when creating this solution must be current fielded platforms as well as the future force. The solution must have the capability to collect and distribute vehicle data to points in the Single Army Logistics Enterprise and the Common Logistics Operating Environment. Also, the solution must have the ruggedization properties to handle the military environment.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

Active Tag

Typical characteristics include a one or two-way radio transceiver (one-way for ID only, locator tags; two-way for tags with data storage and/or interactive command sets) [e.g. user defined tag database query]. These tags may, or may not have memory (either erasable, programmable, or random access) for storage of user defined data, and they have a battery, which is used to send the data back to a reader. Depending on the type of tag, they may also have a CPU, and read only memory to store the tags firmware and allow the tag to respond to user commands (Savi tags have a CPU and ROM, as well as on-board, user defined memory). Active tags typically have far greater read range (up to 300 feet), and often are more omni directional in reader orientation (depending of operating frequency).

Combat Service Support Automated Information System Interface (CAISI)

The US Army's fielded WiFi solution. CAISI nodes use the 802.11b wireless communications protocol and the Air Fortress encryption client.

Automatic Identification Technology (AIT)

Automatic Identification Technology is also called Automated Inventory Tracking. While there are time saving benefits, the most important feature of AIT devices is accuracy. The principles of AIT are quite simple – to acquire data for use in computer based processing, in ways that are automatic, accurate, fast and flexible and involve a degree of identification, be it of items, data or people. The foundations on which these principles are based are soundly rooted in information, coding and pattern recognition theory, but may be transparent to the potential user when seeking to gain a practical business perspective on the applicability and benefits to be gained.

Radio frequency identification (RFID)

RFID uses a system of transponders, more commonly known as "tags" and interrogators. Interrogators emit electronic signals that communicate with the tag, resulting in a visual or audible response answering its call. Interrogators are capable of "reading" or "writing" to the tag, and may be a fixed or a portable handheld device. A system of interrogators and "active" tags, provides in-transit visibility--an accurate accounting of the location of your assets. Active tags have typical characteristics including a one, or two-way radio transceiver (one-way for ID only, locator tags; two-way for tags with data storage and/or interactive command sets) [e.g. user defined tag database query]. These tags may, or may not have memory (erasable, programmable, or random access) for storage of user defined data, and they have a battery, which is used to power the tag. Depending on the type of tag, they may also have a CPU, and read only memory to store the tags firmware and allow the tag to respond to user commands (Savi tags have a CPU and ROM, as well as on-board, user defined memory). Active tags typically have far greater read range (up to 300 feet), and often are more omni directional in reader orientation (depending on operating frequency).

Single Army Logistics Enterprise (SALE)

The Single Army Logistics Enterprise is a network architecture that will be developed using a construct of an end-to-end system of integrated business areas across (primarily) three Enterprise Resource Planning (ERP) programs (i.e. the Logistics Modernization Program (LMP), Global Combat Support System-Army (GCSS-Army) and Product Lifecycle Management Plus (PLM+)) using SAP as the software solution.

Savi Tag

The size of the Savi tag is a function of several components. The most important of which is the antenna design. The current 433.92MHz antenna is a loop antenna that runs most of the length of the tag. This antenna was specifically designed to operate effectively when the tag is attached within the ribs of a metal container, and provide the greatest degree of omni-directional read possible. Tags with smaller antennas reduce the size of the tag; however, these designs significantly reduce the read range of the tag. The two-way radio transceiver, CPU, user-defined memory, and read-only memory and battery account for the remainder of the form factor.